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Clinical Implications of Maxillary Skeletal Expander Placement in Microscrew-Assisted Rapid Palatal Expansion Treatment

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Clinical Implications of Maxillary Skeletal Expander Placement in Microscrew-Assisted Rapid Palatal Expansion Treatment

A thesis submitted in partial satisfaction of the requirements for the degree Master of Science in Oral Biology

by

Hannah R. Bodnar

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ABSTRACT OF THE THESIS

Clinical Implications of Maxillary Skeletal Expander Placement in Microscrew-Assisted Rapid Palatal Expansion Treatment

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Hannah R. Bodnar

Master of Science in Oral Biology

University of California, Los Angeles, 2023

Professor Sanjay M. Mallya, Chair

The specialty of orthodontics aims to optimize patients' skeletal and dental relationships, creating a harmonious orofacial complex and improving facial aesthetics and occlusal function. One common orthodontic problem is transverse maxillary constriction. Clinically, a transverse deficiency in the upper jaw presents as a narrow palate, dental crowding, crossbite, or a combination of these findings. If this orthodontic problem is diagnosed during the primary or mixed dentition years, it can be readily corrected with rapid palatal expansion. However, adult patients may also present with transverse maxillary constriction, which at this stage of skeletal maturation, requires more invasive treatment. Two treatment options that can address transverse deficiency in non-growing patients are surgically-assisted rapid palatal expansion (SARPE) and microimplant-assisted-rapid-palatal Expansion (MARPE). The MARPE technique involves the use of a maxillary skeletal expander (MSE) appliance anchored to the maxilla with mini-screws, applying expansile forces directly to the skeleton, rather than distributing them across the palate and dentition. Symmetric mid-palatal sutural separation is the anticipated therapeutic effect;

however, midfacial changes may occur at other circummaxillary sutures. MARPE treatment outcomes must be evaluated clinically and radiographically. CBCT is the radiographic imaging modality of choice for patients treated with MARPE because of the effects that occur in all three planes of space. Mid-palatal suture measurements, and an abundance of additional information, can be obtained from 3D imaging analysis. The current evidence base surrounding clinical considerations of MSE placement for MARPE therapy is limited. The primary goal of this study was to assess if the skeletal position of MSE mini-screw/temporary anchorage device (TAD) placement influences the magnitude of mid-palatal suture separation and/or is associated with asymmetric skeletal changes during MARPE therapy, using CBCT imaging. We hypothesized that significant differences in mini-screw angulation relative to the palatal plane and the anteroposterior position of the MSE appliance in the hard palate may be associated with asymmetric mid-palatal suture separation. Subjects were grouped based on magnitude of asymmetric separation at the mid-palatal suture. Circummaxillary suture separation symmetry was compared between groups, along with anteroposterior positioning of the appliance, and mini-screw angulation. Our data analyses showed that the only statistically significant correlation for right and left suture separation occurred at the medial pterygoid plate suture in subjects with symmetric mid-palatal suture separation. Analysis of MSE placement and mini-screw angulation in all subjects revealed that the anteroposterior position of the mini-screws is associated with asymmetric expansion, while TAD angulation was not significant. Our findings provide guidance for clinicians’ placement of the MSE appliance in the hard palate. Careful planning and execution of MARPE therapy is likely to lead to improved predictability of mid-palatal suture separation and subsequent changes to other circummaxillary structures.

The thesis of Hannah Bodnar is approved.

Bo Yu

Yong Kim

Sanjay M. Mallya, Committee Chair

University of California, Los Angeles

2023

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LIST OF ABBREVIATIONS

RPE: Rapid Palatal Expander

MARPE: Micro-screw/implant Assisted Rapid Palatal Expansion

SARPE: Surgically Assisted Rapid Palatal Expansion

TAD: Temporary Anchorage Device

MSE: Maxillary Skeletal Expander

FZ: Frontozygomatic

MP: Medial Pterygoid

LP: Lateral Pterygoid

ANS: Anterior Nasal Spine

PNS: Posterior Nasal Spine

ACKNOWLEDGEMENTS

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I would also like to thank my committee members, Dr. Bo Yu and Dr. Yong Kim, for graciously dedicating their time and insights to my thesis. I am honored to have been able to learn from such esteemed faculty and greatly appreciate their suggestions and guidance.

Lastly, and most importantly, I would like to thank my two predoctoral dental student research assistants, Yonatan Maryamian and Nicolette Sameyah. They demonstrated a remarkable enthusiasm for participating in this study and worked tirelessly to collect data for this project. Without their hard work, this project would not have been possible.

INTRODUCTION

The specialty of orthodontics aims to optimize patients' skeletal and dental relationships, creating a harmonious orofacial complex, while improving facial aesthetics and occlusal function. Successful orthodontic treatment requires an accurate diagnosis of the patient's orofacial condition.

A problem-oriented approach to diagnosis facilitates a systematic, comprehensive assessment of the patient's needs. Dental and skeletal problems must be distinguished from one another and further categorized according to the dimension in which they occur. Skeletal transverse maxillary constriction is a common orthodontic issue that can be accompanied by other orthodontic problems in the vertical and anteroposterior dimensions (Figure 1). Transverse maxillary constriction is multifactorial in etiology: genetics, parafunctional habits, or a combination of those factors can contribute to its development. Transverse constriction often presents in the primary dentition years and is best resolved when patients are growing. Maxillary transverse constriction may or may not be associated with a unilateral or bilateral posterior crossbite (Figure 2). In cases of unilateral posterior crossbite, a functional shift of the mandible, to achieve comfortable intercuspation, may be present (Lione et al., 2015). Growing patients with a functional shift may be at risk for asymmetric mandibular development (Lione et al., 2015). Myofascial disturbances and temporomandibular joint disorders also have the potential to be associated with a functional shift due to posterior crossbite (Lione et al., 2015; Preston et al. 2012).

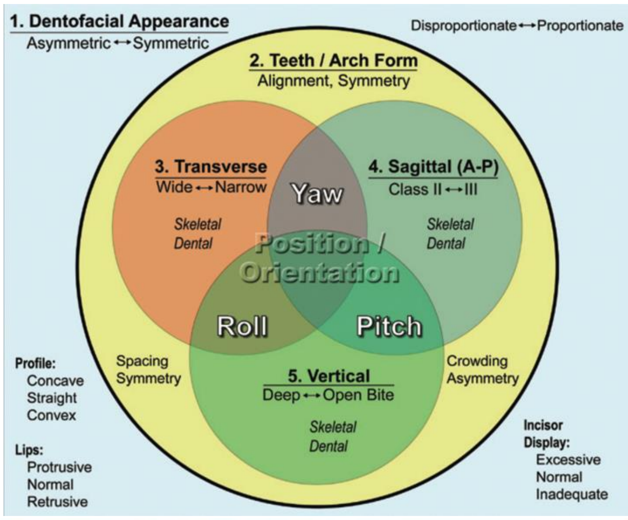


Figure 1. Schematic of orthodontic diagnosis, depicting the various planes of space contributing to dental, skeletal, and facial harmony (Proffit. 2018).

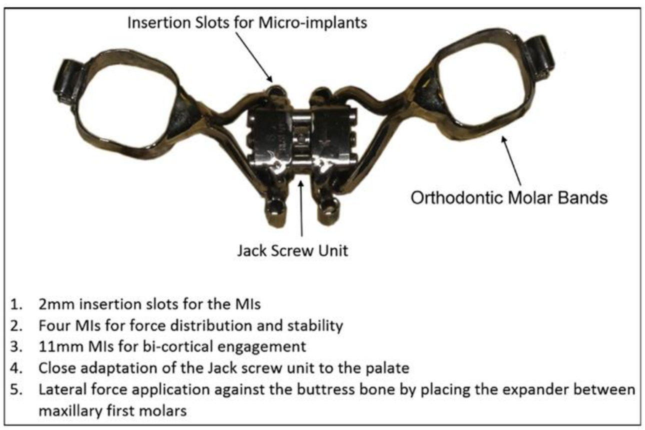
Figure 2. Example of unilateral posterior crossbite (Sant'Anna, 2017).

Numerous studies support rapid palatal expansion (RPE) as an effective treatment for transverse maxillary constriction, especially when rendered in the mixed dentition and early permanent dentition years (Sant'Anna et al., 2017). Skeletal expansion is possible at this time because the craniofacial sutures, including the mid-palatal suture and circummaxillary sutures, are not yet fully ossified (Sant'Anna et al., 2017). When treatment is rendered prior to complete ossification of the sutures, patients can anticipate high success rates and an improved prognosis for morphological and functional correction, and consequently, improved facial development (Sant'Anna et al., 2017).

Prior to growth cessation, RPE can be accomplished with several different orthodontic appliances, the most widely used being a hyrax expander (Figure 3) (Xu, Zou, 2015). Progressive calcification of the craniofacial sutures during growth, however, precludes successful RPE with conventional appliances, limiting treatment to surgical intervention in mature patients. Surgically-assisted rapid palatal expansion (SARPE) is one method utilized to resolve transverse deficiency in non-growing patients. SARPE involves a surgical Lefort I osteotomy of the maxilla and simultaneous interruption of the mid-palatal suture. Post-surgery, the maxillae bones are separated incrementally by activation of an expansion appliance, typically supported by the maxillary first molars (Sant'Anna et al., 2017). As the mid-palatal suture is separated, the circummaxillary sutures are also interrupted, and subsequent midfacial complex distraction occurs (Sant'Anna et al., 2017). Many studies have shown SARPE to be a reliable treatment with high success and predictability; however, surgery presents significant risks of complications and a dramatic increase in total treatment cost (Sant'Anna et al., 2017).

Figure 3. Example of hyrax expander appliance used in RPE treatment (Proffit, 2018)

Microimplant-assisted rapid palatal expansion (MARPE) is a non-surgical treatment technique for transverse skeletal maxillary deficiency in mature patients (Theodorou et al., 2021). Microimplants, miniscrews, or temporary anchorage devices (TADs), terms used interchangeably, are auxiliary anchorage devices utilized to optimize force mechanics in orthodontic treatment. MARPE involves the use of a maxillary skeletal expander expansion appliance anchored to the maxilla with miniscrews and may or may not include components that are supported by the maxillary molars (Figures 4-6). Various maxillary skeletal expander (MSE) designs and activation protocols have been developed. Clinician preference dictates the use of a particular MSE design and activation protocol.



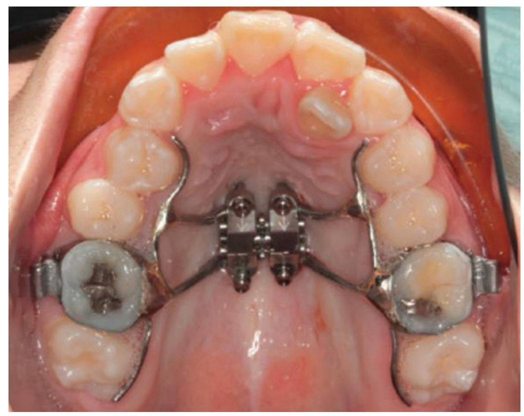


Figure 4. Image of MSE appliance (Sung, 2016)

Figure 5. Example of MSE appliance used in MARPE treatment (Proffit, 2018)

Figure 6. Illustration of mini-screws (Proffit, 2018).

MARPE treatment differs from tooth-borne palatal expansion in that the mechanical forces expansile forces are directly applied to the maxillae bones, rather than to the dentition or the periodontal apparatus. Clinical studies have shown MARPE treatment to be highly successful. One study reported successful sutural separation in 86.96% of patients, aged 20.9 years, with stable results, at 30 months follow-up (Sant'Anna et al., 2017). The mean separation of the mid-palatal suture at PNS was about 81.78% of that at ANS, demonstrating that the appliance created a generally parallel split of the mid-palatal suture (Shin et al., 2021). (Figure 7). MARPE efficacy must be evaluated clinically and radiographically. Though often apparent clinically, evidenced by the presence of a midline diastema, radiographic confirmation of sutural separation is required (Sant'Anna et al., 2017). A CBCT scan or occlusal intraoral radiograph must be used to evaluate suture separation (Gohl et al., 2010).

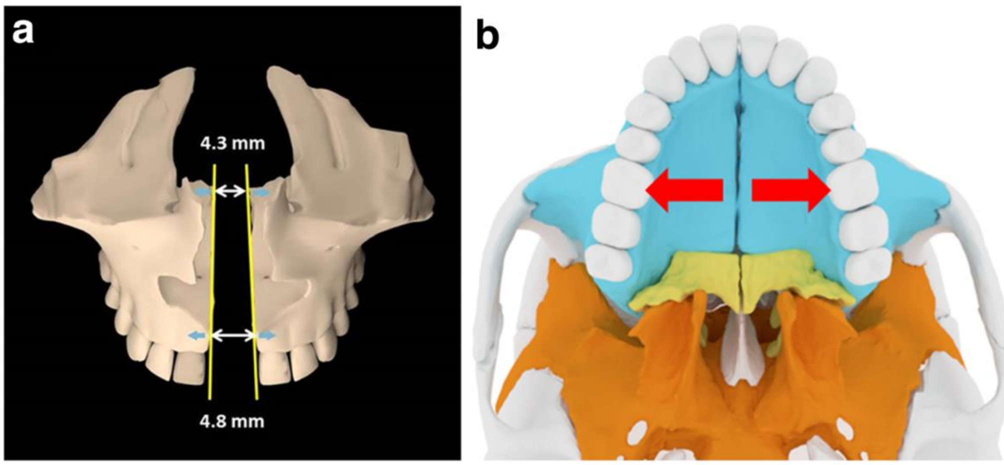


Figure 7. Sagittal parallelism of midpalatal suture opening obtained with MARPE. Borders of the midpalatal suture (yellow lines) moving almost perfectly parallel to each other; amount of split at PNS (4.3 mm) was 90% of that at ANS (4.8 mm) (Cantarella et al., 2017).

Though MARPE treatment is less invasive and presents fewer risks than SARPE, complications are still possible. The most common MARPE therapy complications include TAD failure and asymmetric skeletal expansion. In a clinical study conducted by Payne, seventy-seven subjects were evaluated for asymmetric expansion, measured by comparing pre- and post-treatment CBCT images. 47% of these patients exhibited asymmetry greater than 1 mm, with an average of about 1.47 mm at ANS. No correlation, however, was found between the amount of asymmetric expansion and patient age, molar inclination, palatal thickness, posterior screw expansion, and palatal vault height (Payne, 2021). The current evidence base surrounding predictive factors of MARPE failure is limited; our study investigates appliance factors that may be associated with decreased MARPE success.

Overall Objectives and Specific Aims

Objective: The primary goal of this study is to determine if maxillary skeletal expander (MSE) position is associated with asymmetric expansion in microscrew-assisted rapid palatal expansion (MARPE), evaluated by cone beam computed tomography (CBCT) analysis.

Specific Aims:

The first aim of this study is to determine if the anteroposterior skeletal position of the mini-screw/temporary anchorage devices (TADs) in the MSE appliance, influences symmetric expansion along the mid-palatal suture.

The second aim of this study is to identify suture changes after MARPE therapy at the frontozygomatic suture, and the medial and lateral pterygoid plates.

Lastly, we aim to assess if TAD angulation is associated with asymmetric circummaxillary suture changes.

Experimental Design & Methods

This retrospective study was conducted at the University of California Los Angeles (UCLA) with approval by the ethics committee. The study utilized patient data previously acquired in the UCLA School of Dentistry for management of patients undergoing MARPE treatment conducted in the UCLA Section of Orthodontics. The data was accessed through the School of Dentistry's electronic patient database, Axium, and imaging software, Dolphin Imaging, and protected health information (PHI) was removed.

Previous studies related to MARPE efficacy have included study populations as few as 15 subjects, thus, a sample size of 24 was determined as having sufficient power for our research. Table X shows the study population demographics.

Pre-treatment CBCT records from consecutively-selected MARPE-treated patients from the years 2015-2020, seen by resident clinicians at the UCLA Section of Orthodontics clinic were selected for this study. Our inclusion criteria required that patients be treated in the residency clinic at the UCLA Section of Orthodontics and have pre- and post-treatment CBCT images obtained at UCLA. All CBCT scans were acquired using the Accuitomo170 (J Morita, Kyoto, Japan) and Veraviewepochs 3De (J Morita, Kyoto, Japan). Patients excluded from this study had pre- and/or post-treatment CBCT images obtained outside of UCLA or had CBCT's with poor image quality and/or resolution. The presence of a craniofacial deformity, obfuscation of critical dental landmarks, broad prosthetic restorations, or multiple missing teeth also rendered patients unsuitable for participation in this study.

The data acquired for each patient included the following:

1. Date of birth
2. Pre-treatment CBCT scan
3. Post-treatment CBCT scan

4. Pretreatment Measurements (Figure 8)
    1. Coronal Measurements
        a. Distance from vertical line extending from midline crista galli to right and left frontozygomatic sutures
    2. Axial Measurements
        a. Distance from vertical line extending from midline crista galli to medial-most point on right and left lateral pterygoid plates
        b. Distance from vertical line extending from midline crista galli to lateral-most point on right and left medial pterygoid plates

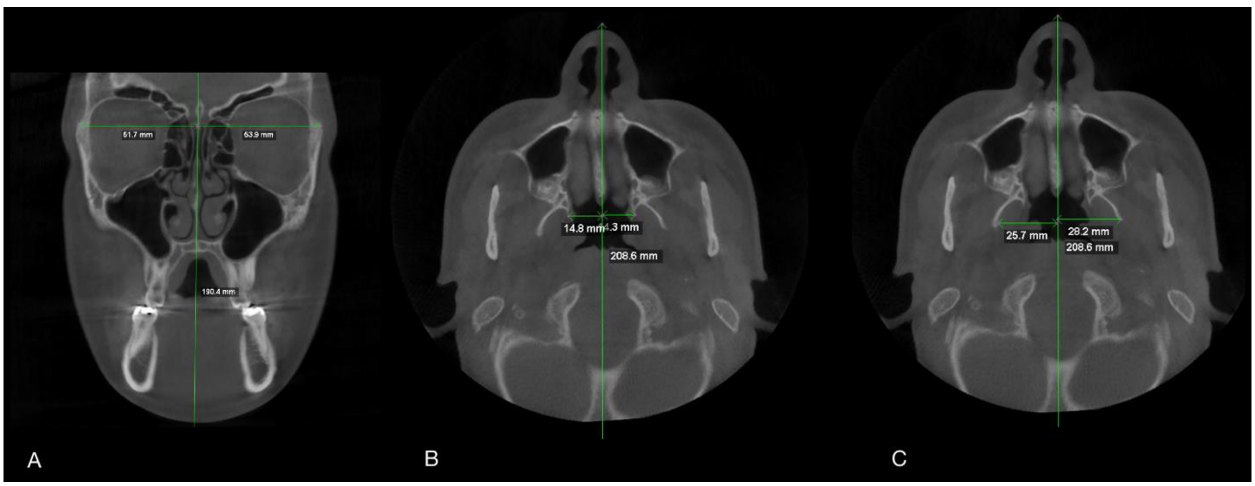


Figure 8. Coronal and axial CBCT slices of subject in symmetric group pre-treatment. (A). R and L measurement of frontozygomatic suture. (B). R and L measurement of medial pterygoid plates (C). R and L measurement of lateral pterygoid plates.

Post-treatment Measurements (Figures 9-11)

1. Coronal Measurements
    a. Distance from vertical line extending from midline crista galli to right and left frontozygomatic sutures

b. Angulation of anterior right and left TADs relative to the palatal plane

c. Angulation of posterior right and left TADs relative to the palatal plane

2. Axial Measurements

a. Distance from vertical line extending from midline crista galli to medial-most point on right and left lateral pterygoid plates

b. Distance from vertical line extending from midline crista galli to lateral-most point on right and left medial pterygoid plates

c. Distance between maxillae bones at the anterior nasal spine

d. Distance between maxillae bones at the posterior nasal spine

3. Sagittal Measurements

a. Total distance between anterior nasal spine and posterior nasal spine

b. Distance from posterior nasal spine to posterior TAD

c. Distance from anterior nasal spine to anterior TADs

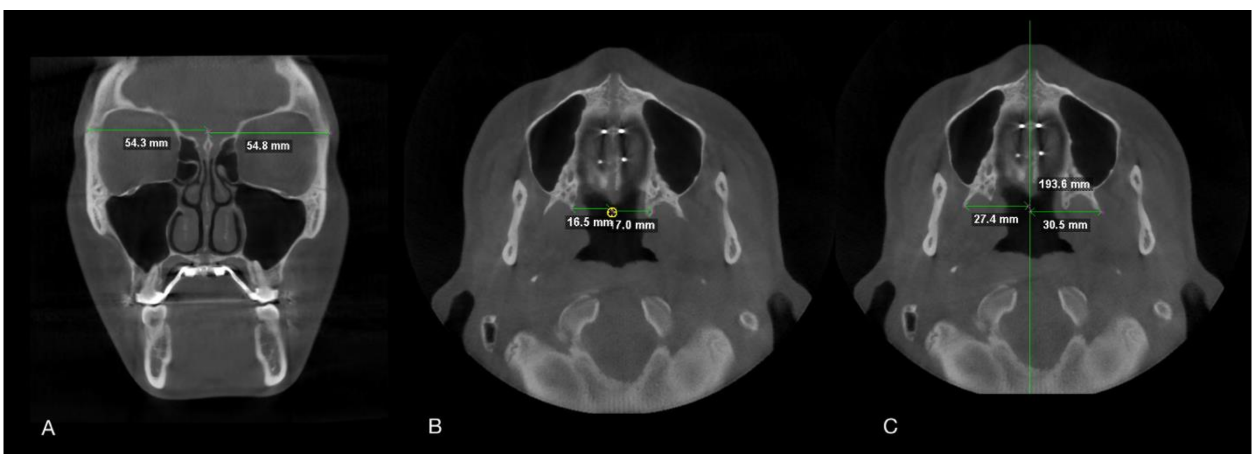


Figure 9. Coronal and axial CBCT slices of subject in asymmetric group with MSE appliance. (A). R and L measurement of frontozygomatic suture. (B). R and L measurement of medial pterygoid plates (C). R and L measurement of lateral pterygoid plates.

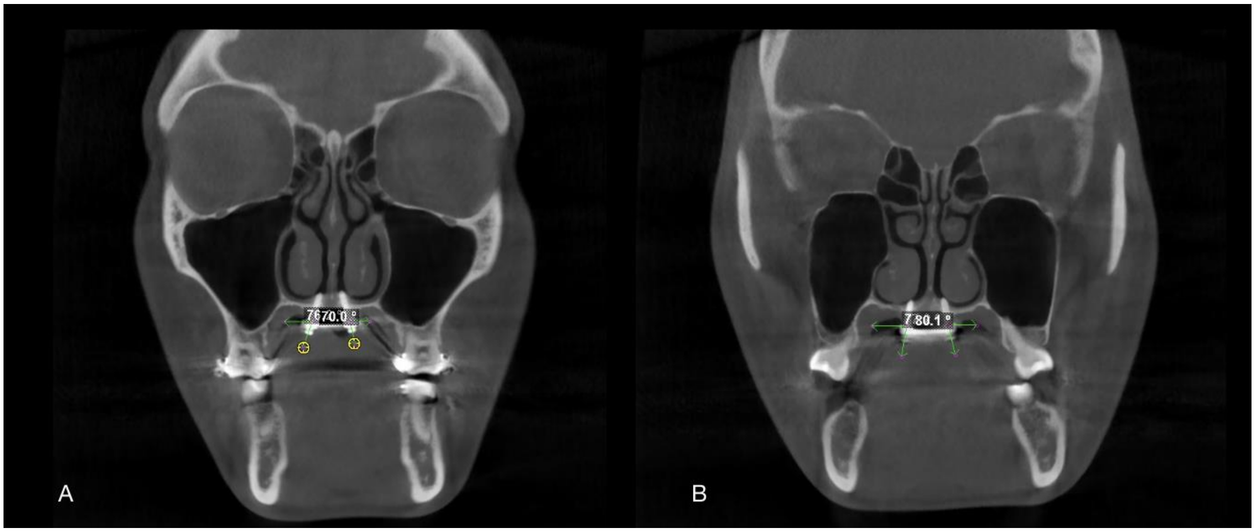


Figure 10. Coronal CBCT slices of subject in asymmetric group with MSE appliance. (A). R and L anterior TAD angulation measurements. (B). R and L posterior TAD angulation measurements.

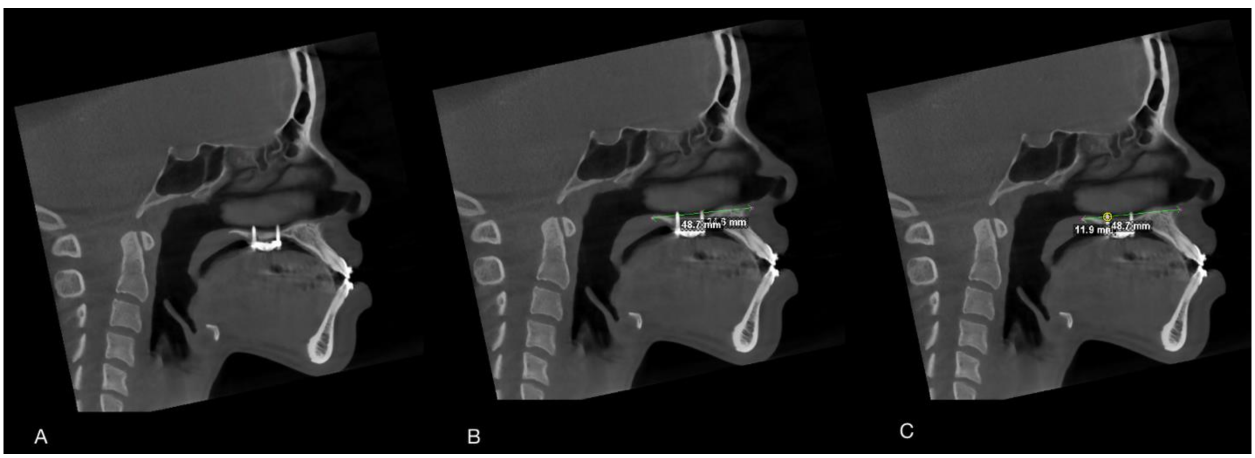


Figure 11. Sagittal CBCT slices of subject in asymmetric group. (A). Visualization of MSE appliance in hard palate. (B). Measurement from ANS to PNS + anterior TAD to ANS. (C). Measurement from ANS to PNS + posterior TAD to PNS.

Two UCLA predoctoral dental students and one orthodontic resident will be designated as evaluators. Inclusion criteria for the evaluators are as follows:

1. UCLA predoctoral or postdoctoral dental student/resident
2. Trained to obtain CBCT measurements in Dolphin Imaging software
3. Committed to dedicate time to the study

Two-dimensional CBCT slices acquired from three-dimensional CBCT volumes were utilized to assess the magnitude of skeletal change associated with MARPE treatment. Evaluators compared predetermined hard tissue points on pre- and post-treatment CBCT images. Quantitative comparisons were made using measurements obtained from pre- and post-treatment images. Hard tissue point measurement methods for this study were based, in part, on Cantarella's study. (Cantarella, 2017). Statistical analysis of the collected data was performed using Prism 10 software. All analyses utilized an alpha value of 0.05 and a p value of 0.05.

RESULTS

Suture Separation

Previous studies have demonstrated that during expansion, sutural separation along the mid-palatal suture occurs symmetrically, such that the width between the maxillae bones post-expansion observed at ANS is equal to that at PNS. In this study, subjects were classified as having asymmetric expansion if the ratio of ANS to PNS distance deviated from 1.0 by 0.4 or more. Nine subjects demonstrated asymmetric mid-palatal sutural separation based on these criteria.

Suture separation was further evaluated by measuring the distance from the midline to three other circummaxillary sutures. The suture landmarks used were the lateral-most point of the frontozygomatic suture, the lateral-most point on the medial pterygoid plate, and the most medial point on the lateral pterygoid plates. The specific landmark points of derived from Cantarella's study (Cantarella, 2017). Crista galli served as the midline reference point; a vertical line was extended inferiorly so that measurements from the lateral landmarks were made perpendicular to the vertical line. Our data demonstrate that the only statistically significant correlation that exists between right and left suture separation was for the medial pterygoid plate suture in the symmetric group (Tables 4-5; Figures 12, 13).

Tables 1-3 show subject demographics for the asymmetric and symmetric groups.

Table 1. Descriptive for age in both groups; all units in years, total N = 24

	Asymmetric Group	**Symmetric Group**
Mean Age at T1	20.5	18.36
Lower Limit	12.33	7.08
Upper Limit	36.42	33.42
Range	24.09	26.34

Table 2. Sex of subjects for both groups, total N = 24

	Asymmetric Group	**Symmetric Group**
Male	3	18.36
Female	6	7.08

Table 3. Descriptive statistics for race/ethnicity in both groups; total N = 24

	Asymmetric Group	**Symmetric Group**
Asian	3	2
Hispanic	3	5
White/Caucasian	2	3
Black	0	1
Other	1	4

Table 4. Correlation of R and L Suture Separation in Symmetric Subjects; alpha value for significance = 0.05; N = 15

Sutures	**Frontozygomatic**	**Medial Pterygoid Plate**	**Lateral Pterygoid Plate**
Spearman r			
r	0.05745	-0.6647	0.3754
95% CI	-0.4816 - 0.5649	-0.8766 - -0.2369	-0.1635 - 0.7417
P value			
P (two-tailed)	0.8378	0.0061	0.1514
Significant	No	Yes	No

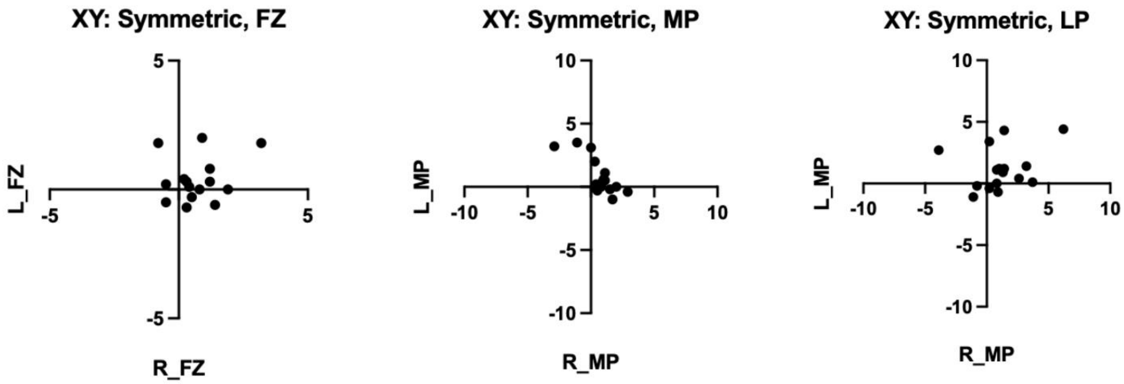


Figure 12. Right and left frontozygomatic, medial pterygoid plate, and lateral pterygoid plate suture separation correlation plots for symmetric mid-palatal suture separation subjects.

Table 5. Correlation of Right and Left Circummaxillary Suture Separation in Asymmetric Subjects; alpha value for significance = 0.05; N = 9

	Frontozygomatic	Medial Pterygoid Plate	Lateral Pterygoid Plate
Spearman r			
r	-0.3486	-0.2585	-0.09726
P value			
P (two-tailed)	0.3186	0.4682	0.7917
Significant	No	No	No

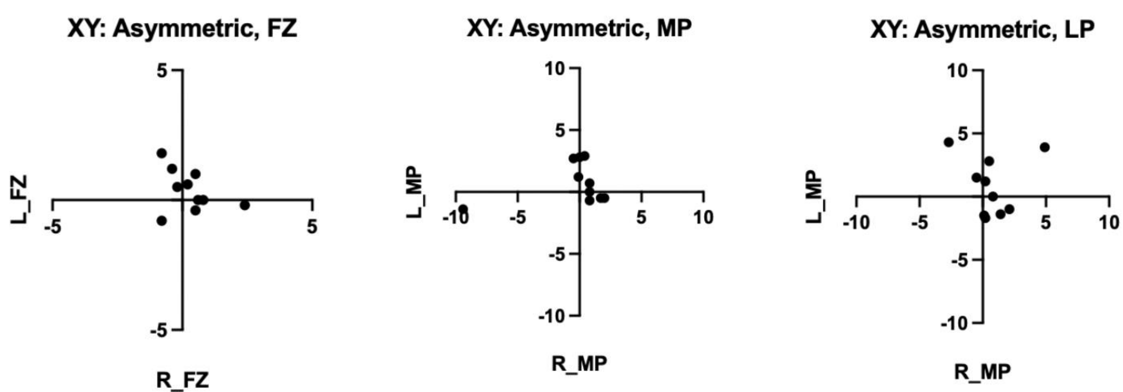


Figure 13. Right and left frontozygomatic, medial pterygoid plate, and lateral pterygoid plate suture separation correlation plots for asymmetric mid-palatal suture separation subjects.

MSE Position and Association with Sutural Separation

Mini-screw expanders are custom-made appliances, specific to a patient's hard palate anatomy. An alginate impression or digital scan of the patient's maxillary dentition and hard palate is obtained so that the clinician can mark the desired location of the TADs on the hard palate. The appliance is fabricated by a laboratory according to the markings made on the cast. We hypothesized that the location of the TADs may influence asymmetric expansion at the mid-palatal suture. An appliance placed closer to ANS may result in a greater magnitude of expansion at ANS than at PNS.

Descriptive statistics were calculated for anterior and posterior TAD position in both symmetric and asymmetric groups (Tables 6-8; Figures 14-17).

Table 6. Descriptive statistics for anterior and posterior TAD position in asymmetric and symmetric groups; asymmetric group N = 9, symmetric group N = 15

	Anterior Asymmetric	**Anterior Symmetric**	**Posterior Asymmetric**	**Posterior Symmetric**
Minimum	0.40	0.43	0.13	0.050
Maximum	0.58	0.72	0.36	0.30
Range	0.18	0.29	0.23	0.25
Mean	0.49	0.55	0.28	0.21
Std. Deviation	0.04944	0.07482	0.06509	0.07088
Std. Error of Mean	0.01648	0.01932	0.02170	0.01830

Table 7. ANOVA summary for anterior TAD position in symmetric and asymmetric groups; asymmetric group N = 9, symmetric group N = 15

Source of Variation	**% of Total Variation**	**P Value**	**P Value Summary**	**Significant**	
Row Factor	56.61	0.3198	ns	No	
Column Factor	28.88	0.0131	*	Yes	
ANOVA Table	**SS (Type III)**	**DF**	**MS**	**F (DFn, DFd)**	**P Value**
Row Factor	0.06968	14	0.004977	F (14, 8) = 1.410	0.03198
Column Factor	0.03556	1	0.03556	F (1, 8) = 10.07	0.0131
Residual	0.02824	8	0.003531		
Difference Between Column Means					
Predicted (LS) mean of Asym	0.4658				
Predicted (LS) mean of Sym	0.5547				
Difference between Predicted Means	-0.08889				
SE of Difference	0.02801				
95% CI of Difference	-0.1535 - -0.02430				

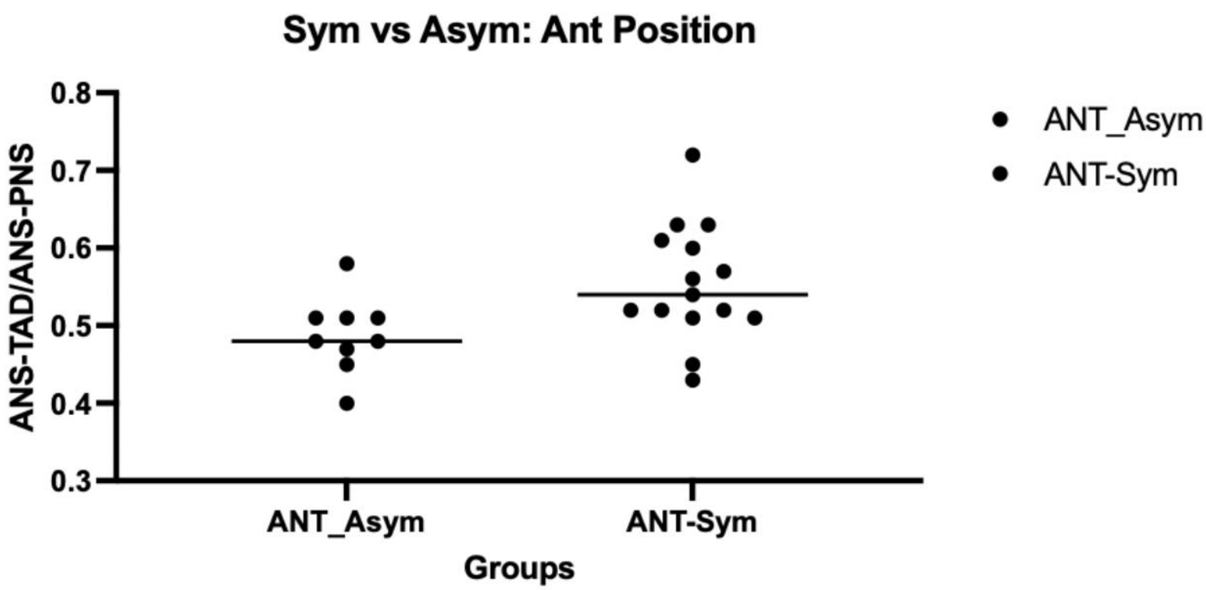


Figure 14. Comparison of anterior TAD placement between asymmetric and symmetric groups

Table 8. ANOVA summary for Posterior TAD position in symmetric and asymmetric groups; asymmetric group N = 9, symmetric group N = 15

Source of Variation	% of Total Variation	P Value	P Value Summary	Significant	
Row Factor	52.22	0.4815	ns	No	
Column Factor	24.03	0.0304	*	Yes	
ANOVA Table	**SS (Type III)**	**DF**	**MS**	**F (DFn, DFd)**	**P Value**
Row Factor	0.06792	14	0.004857	F (14, 8) = 1.069	0.4815
Column Factor	0.03125	1	0.03125	F (1, 8) = 6.887	0.0304
Residual	0.03630	8	0.004538		
Difference Between Column Means					
Predicted (LS) mean of Asym	0.2967				
Predicted (LS)	0.2133				

mean of Sym	
Difference between Predicted Means	0.083333
SE of Difference	0.03175
95% CI of Difference	0.01011 to 0.1566

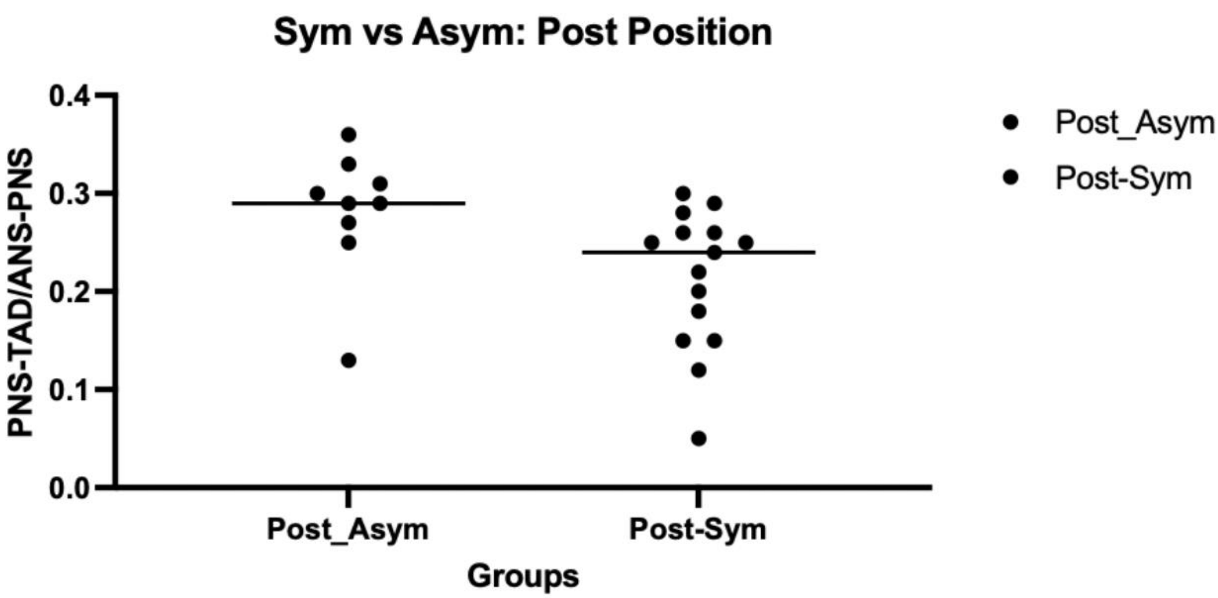


Figure 15. Comparison of posterior TAD placement between asymmetric and symmetric groups

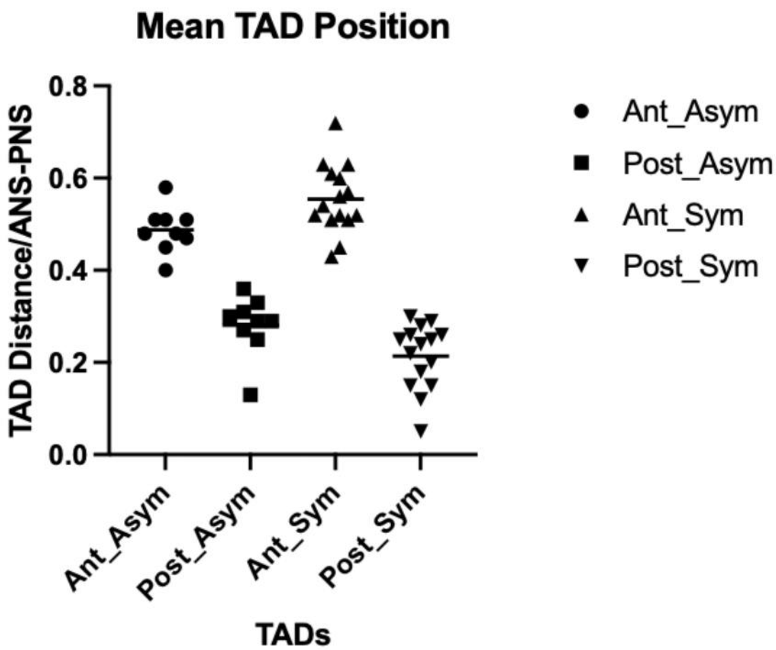


Figure 16. Comparison of posterior TAD placement between asymmetric and symmetric groups

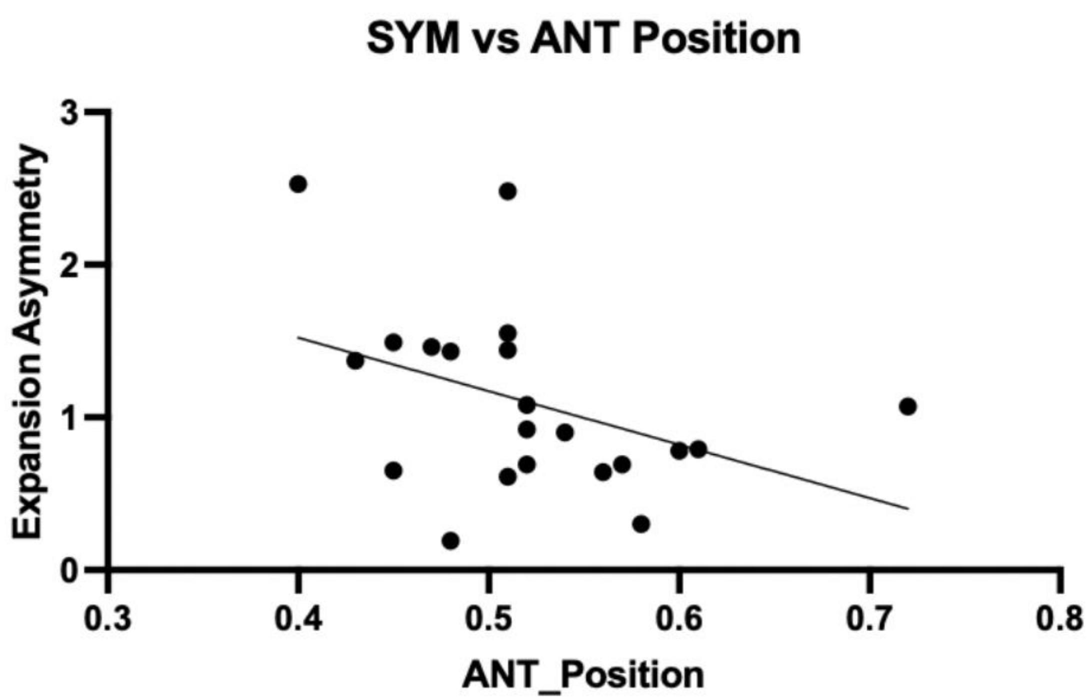


Figure 17. Simple linear regression model for anterior position of TAD in symmetric subjects y = -3.502*X + 2.923. Slope: -3.502

TAD/Mini-Screw Angulation

Mini-screw angulation measurements were obtained for the two anterior and two posterior TADs supporting the MSE. Coronal cross-sectional images at the location of the MSE's anterior TADs and posterior TADs were used to obtain measurements of the mini-screws' angulations. Two rays were drawn for each TAD: one line was superimposed over the palatal plane, the other, along the orientation of the screw, such that the vertex of the angle created by these vectors equals the point at which the mini-screw penetrates the hard palate. The ideal position of TADs used in an MSE appliance is 90 degrees relative to the palatal plane. An obtuse angle indicates the screw tip is pointed laterally, relative to the midline; an acute angle indicates the screw is pointed medially. Descriptive statistics for left and right TAD angulation in asymmetric and symmetric groups were calculated (Tables 9-10; Figure 18). TAD angulations were compared using a Kruskal-Wallis Test; no statistically significance difference was detected (Table 11).

Table 9. Descriptive statistics for left TAD angulation in asymmetric and symmetric groups; asymmetric group N = 9, symmetric group N = 15

Left TADs	Anterior Asymmetric	Anterior Symmetric	Posterior Asymmetric	Posterior Symmetric
Minimum	75.70°	76.00°	65.70°	56.80°
Maximum	105.9°	104.0°	109.8°	102.9°
Range	30.20°	28.00°	44.10°	46.10°
Mean	89.51°	89.74°	87.57°	84.33°
Std. Deviation	9.008	9.096	13.20	11.50
Std. Error of Mean	3.003	2.348	4.401	2.970

Table 10. Descriptive statistics for right TAD angulation in asymmetric and symmetric groups; asymmetric group N = 9, symmetric group N = 15

Right TADs	**Anterior Asymmetric**	**Anterior Symmetric**	**Posterior Asymmetric**	**Posterior Symmetric**
Minimum	70.00°	63.30°	39.70°	57.30°
Maximum	101.6°	99.90°	108.9°	101.7°
Range	31.60°	36.60°	69.20°	44.40°
Mean	86.02°	83.47°	82.34°	82.57°
Std. Deviation	10.73	10.64	22.32	12.32
Std. Error of Mean	3.575	2.748	7.439	3.181

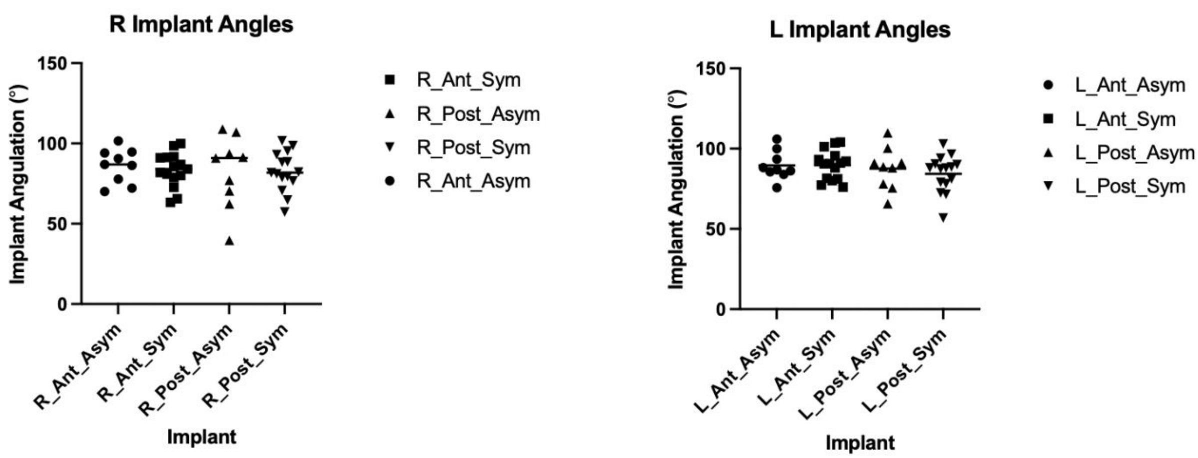


Figure 18. Median values for right implant angulation in symmetric and asymmetric groups

We anticipated that TAD angulation relative to the palatal plane, varying more than 5 degrees from the ideal 90 degree perpendicular, would result in compromised mid-palatal suture separation. Additionally, we expected variability between right and left TAD angulation to contribute to asymmetric movement of the maxillae bones, pterygoid plates, and frontozygomatic sutures. Our descriptive statistics and Kruskal-Wallis analysis demonstrate that TAD angulation does not significantly contribute to asymmetric changes.

Table 11. Right and left TAD angulations in each group were compared using a Kruskal-Wallis test

Kruskal-Wallis Test	**Right TADs**	**Left TADs**
P value	0.09545	0.5819
Exact or Approximate	Approximate	Approximate
Median Variation Significance ($p < 0.05$)	No	No
Kruskal-Wallis Statistic	0.3288	0.3186

DISCUSSION

We anticipated a correlation to exist between right and left suture separation at the frontozygomatic, and medial and lateral pterygoid plate sutures. Based on our correlation analyses, the only statistically significant finding was at the medial pterygoid plate in the symmetric group. Though this data is statistically significant, its clinical significance is negligible.

Our study aimed to assess if the skeletal position of MSE mini-screw/TAD placement is associated with asymmetric mid-palatal suture separation and/or other asymmetric circummaxillary suture changes during MARPE therapy. Our findings suggest that the more anteriorly-positioned the anterior TADs of the appliance are placed, the greater the magnitude of expansion at ANS. Greater expansion at ANS relative to PNS, by 40% or more was associated asymmetric changes at the other circummaxillary sutures assessed in our study.

TAD angulation was found to be a non-significant factor in suture separation symmetry. The information gained from this study provides clinical guidance for placement of TADs used in MSE appliances. Careful planning and execution of MSE TAD placement may lead to greater predictability of mid-palatal and circummaxillary suture separation, and ultimately improved overall orthodontic outcomes.

The primary limitations of our study were procedural in nature. Hard tissue points on the CBCT volumes were manually selected by trained, calibrated evaluators; however, an inter-evaluator reliability of 1.0 could not guaranteed, nor is plausible. Due to the small magnitude of the measurements obtained, point selection errors resulted in a relatively large margin of error. The small sample size analyzed in this study also limits the statistical power of our results; future studies should aim to obtain a greater number of subjects to strengthen statistical power and generalizability of findings. This study posed a negligible risk to subjects, though, the risk of protected health information breach should not be dismissed. Additionally, the time between initial and post-treatment CBCT acquisition was not standardized. The true amount of expansion obtained may have been misrepresented, if subjects had a CBCT acquired after significant ossification occurred at the mid-palatal suture, as opposed to immediately following cessation of MSE activation. In the future, a prospective study should be designed such that CBCT imaging intervals are standardized among subjects.

The data obtained in this study provide a foundation for further investigation of additional variables related to asymmetric expansion during MARPE therapy. Additional future research could investigate if an association exists between pre-existing skeletal asymmetry and asymmetric expansion. MSE activation frequency and magnitude of mid-palatal suture separation are additional variables that could also be considered in future studies.

CONCLUSIONS

- No clinically significant correlation exists between right and left suture separation at the frontozygomatic, lateral pterygoid plate, and medial pterygoid plate sutures in patients treated with MARPE therapy.
- Asymmetric mid-palatal suture separation is more likely to occur the more anteriorly placed the anterior TADs are positioned on the hard palate.
- Asymmetric separation of the frontozygomatic, lateral pterygoid plate, and medial pterygoid plate sutures is associated with asymmetric expansion at the mid-palatal suture, quantified by a ratio of expansion of ANS:PNS of greater than or equal to 1.4.
- Singular TAD angulation deviating from 90 degrees and TAD angulation variability within an appliance were not found to be associated with asymmetric mid-palatal suture separation

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